-continued

pulse)

A qualitative description of the output of the amplifier is shown in FIG. 1C. It is substantially the same as the pulse train shown in FIG. 1B except the pulses are amplified in energy by a factor of about 133,000.

Preferred sizes of the X-ray point source for proximity lithography is in the range of a few 100 μm (e.g., 500 μm) in diameter to about 1 mm in diameter. A 500 μm spot simulated from 20 μm diameter pulses is shown in FIG. 5. In order to achieve the proper spot size with the above described system, we have to hit the target at different spots (e.g., multiple 20 μm spots **52** spread over a 500 μm area **50**). This can be accomplished by a mirror mounted on a fast 2 axis PZT **48** that would steer the beam slightly over the required area as shown in FIG. **1**.

The above system provides very good X-ray conversion. However, a somewhat better X-ray conversion can be accomplished with higher frequency beams. In a study by Lawrence Livermore laboratories, a 15 percent conversion efficiency was observed when the laser wavelength was 532 nm (doubled 1064 nm) versus 10 percent conversion efficiency for 1064 nm. A doubling crystal can be placed at the output beam from the amplifier in order to utilize the higher X-ray conversion efficiency at 532 nm.

While the above description contains many specificities, the reader should not construe these as limitations on the scope of the invention, but merely as exemplifications of preferred embodiments thereof. Those skilled in the art will envision many other possible variations which are within its scope.

For example, we could choose a much shorter pulse duration than 100 ps. These could be obtained using a passive saturable absorber instead of the acousto-optic mode locker. With a saturable absorber we can get femtosecond pulses. It is our belief that the advantage of pulses in the 100 ps range is that we get some heating of the plasma whereas the very very short pulses creates the plasma but provides very little heating of it. The energy per pulse needs to be in the range of 80 mJ/pulse when the objective lens is about 12 cm from the target. A distance of at least 12 cm is recommended to avoid contaminating the lens with target material. However, if this distance is reduced the required energy per pulse could be reduced accordingly because we could focus on a smaller spot. By doing so we could reduce the energy per pulse requirement from about 80 mJ/pulse to as low as about 10 mJ/pulse.

The cost of laser diodes for pumping solid state lasers is primarily dominated by the peak power requirements and this determines the number of diode bars. By operating the bars at a relatively high duty factor of 20 percent and generating a large number of pulses per second, we can minimize the initial cost of the diode pumping system. For example, a 1 KW system may require 3 KW average power from the pump diodes, a 20 percent duty factor diode array system would require 15 KW peak power. Using 50 Watt peak bars at $700 per bar, the system would cost $210,000. In comparison, a 1 percent duty factor system would require 300 KW peak power. The cost would be $4,000,000. Increasing the duty factor above 20 percent, all the way to CW is feasible, but, balancing all factors we prefer a duty factor of about 20 percent. Persons skilled in the art will recognize that a flash lamp pumping system could replace the diode pumping system.

The seed beam pulse train frequency could be in the range of 10 MHz to 200 MHz or greater. With some compromise in the average power the number of pulses per second could be reduces down to about 1,000 Hz. High repetition rate mode locked Q-switched systems can be used to generate pulses that are composed of multiple pulses for prepulse applications. The amplifier can be of slab or rod design. The solid state material can be of a host material other than Nd:YAG. For example, Nd:YLF, Cr:LiSAF, Ti:S, etc. could be used. The steering mirror can be any reflecting element that would be appropriate to generate the cluster of spot sizes desired, such as the 20 μm spots.

Other devices could be substituted for the electro-optic modulator for pulse spacing, such as cavity dumping or even an optical rotary interrupter. The pulse spacing devices would in most applications remove a very large percentage of the pulses in the seed beam such as more than 99 percent as in the preferred embodiment described; however, We could imagine applications where as the percentage remove might be as low as 80 percent. The number of passes through the amplifier can be as high as eight. Systems with eight passes are clearly feasible.

Accordingly the reader is requested to determine the scope of the invention by the appended claims and their legal equivalents, and not by the given examples.

We claim:

1. A high average power, high brightness solid state pulse laser device comprising:

a) a laser means for producing a first pulse laser beam with a high pulse frequency and very short pulse duration of less than 1 ns,

b) a pulse spacing selector means for removing from said first pulse laser beam more than 80 percent of the pulses in said beam to produce a second pulse laser beam comprising high frequency pulses in excess of 1,000 pulses per second,

c) a laser amplifier means for amplifying said second pulse laser beam to produce an amplified pulse laser beam comprising high frequency pulses, said amplified pulse laser beam having an average power in excess of 10 Watts,

d) a focusing means for focusing said amplified pulse laser beam to a small spot size on a target, said spot size being small enough to produce a brightness level in excess of 10^{11} W/cm^2.

2. A pulse laser device as in claim **1** and further comprising a beam steering means for rapidly steering said amplified pulse laser beam relative to said target so as to simulate a spot size larger than said small spot.

3. A pulse laser device as in claim **2** wherein said beam steering means comprises a PZT device attached to a mirror.

4. A pulse laser device as in claim **1** wherein said beam steering means comprises a means for moving said target relative to said amplified pulse laser beam.

5. A pulse laser device as in claim **1** wherein laser means comprises a mode locked laser oscillator comprising a mode locking means for causing said laser means to produce said first pulse laser beam.

6. A pulse laser device as in claim **5** wherein said mode locking means is an acousto-optic mode locker.

7. A pulse laser device as in claim **1** where in said pulse selector means comprises an electro-optic modulator.